BY MACHEL ALLEN

PHYSICS-BASED TRANSFER LEARNING AND ARTIFICIAL INTELLIGENCE

PRODUCT OVERVIEW

The Product forms a brain-to-machine-interface (BMI) that facilitates direct brain-control.

PRODUCT DESCRIPTION

The Product is designed to facilitate direct control of space/surface vehicles without the use of the limbs. This works perfectly for persons having a handicap that hinders motor skills or for health persons who may prefer not to use limbs. The operators of this device can issue instructions to these vehicles with direct input from the brain. The Vehicles will receive instructions to direct its movement and operations. Users will be able to connect wired or wirelessly to the vehicles.

PHYSICS-BASED TRANSFER LEARNING

Physics-Based Transfer Learning is where one trains the model for one task and uses the knowledge learned from that task to perform another task. (B.V. Elsevier, 2019)

Transfer learning (TL) is a research problem in machine learning (ML) that focuses on storing knowledge gained while solving one problem and applying it to a different but related problem. For example, knowledge gained while learning to recognize cars could apply when trying to recognize trucks. This area of research bears some relation to the long history of psychological literature on transfer of learning, although formal ties between the two fields are limited. From the practical standpoint, reusing or transferring information from previously learned tasks for the learning of new tasks has the potential to significantly improve the sample efficiency of a reinforcement learning agent. (Jeremy West et al., 2007) (George Karimpanal et al., 2019)

ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI), sometimes called machine intelligence, is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and animals. Leading AI textbooks define the field as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. Colloquially, the term "artificial intelligence" is often used to describe machines (or computers) that mimic "cognitive" functions that humans associate with the human mind, such as "learning" and "problem solving". (Russell and Norvig, 2009) (Poole, Mackworth and Goebel, 1998)

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THE HUMAN BRAIN: NEURO-TRANSMITTANCE

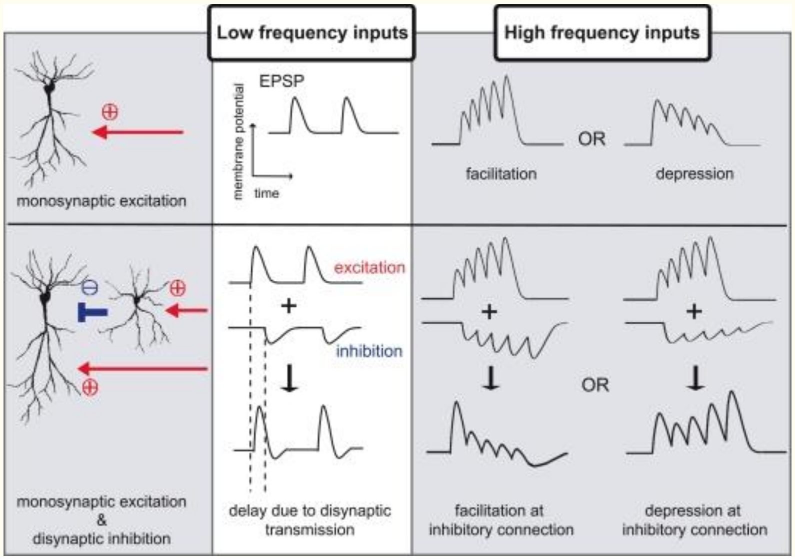
A number of studies suggest that the brain exhibits functional localization, i.e. each brain region has a somewhat specialized role (Boling et al., 2002; Passingham et al., 2002). Most animal behaviors require the coordinated activity of sensory, integrative and motor brain areas. As the sensory landscape undergoes change, the interaction among brain areas should also be dynamic and change depending on the situation. For example, when you meet a new person, initially you may try to memorize his or her face (encoding information), but the next time you see this person, you will recognize his or her face and may remember several events associated with this person (retrieving information). Given that the synaptic transmission between neurons is a basic unit of information processing, it is crucial to understand how synaptic modulation can change interactions among brain areas. (Erin M. Schuman, 2008)

Neurotransmitters, such as dopamine, norepinephrine, serotonin, or acetylcholine, play an important role in state-dependent modulation of the brain (Kodama et al., 2002; Robbins, 2005; Takakusaki et al., 2006). These neurotransmitters, often called neuromodulators, are synthesized and released from a relatively small number of specialized neurons, which are primarily located in several distinct nuclei in the basal forebrain, midbrain or brainstem (Siegel et al., 1999). Through long-range connections these neuromodulator-releasing neurons make synaptic contacts with many different brain areas. Neuromodulators released from synaptic terminals are also capable of diffusing over substantial distances (>10 μm) and can act on receptors remote from release sites (volume transmission; Venton et al., 2003; Zoli et al., 1998). Thus, at the apparent cost of spatial selectivity, the information from neuromodulator-releasing neurons can be broadcast to a large area of the brain. As such, activity changes in a small number of neurons can exert a broadcast influence on many brain areas, coordinating a functional change across areas (Hasselmo, 1995).

In electroencephalograms or local field potential recordings, the brain activities are observed as multiple oscillators at different frequencies. A number of studies have described apparent links between specific oscillatory activities and particular brain functions (Buzsaki and Draguhn, 2004; Osipova et al., 2006; Palva and Palva, 2007). These oscillatory activities are not just epiphenomena, but the brain appears to utilize them for information coding, for example, to bind distributed information in the cortex (Engel et al., 2001; Varela et al., 2001) or to select phase-locked activities (Laurent, 2002). These results imply that oscillatory activities may play an important role in regulating information flow in the brain. Thus, it is worthwhile to assess how a neuronal network will respond to different frequency stimulation.

In monosynaptic transmission, the magnitude of the postsynaptic response evoked by presynaptic stimulation is intrinsically dependent on stimulation frequency (Markram et al., 1998). For example, during the delivery of multiple stimuli at close time intervals, the size of postsynaptic potentials can become larger or smaller, phenomena known as paired-pulse facilitation or depression, respectively (Zucker and Regehr, 2002). Both presynaptic and postsynaptic

mechanisms have been implicated in these processes. For example, changes in neurotransmitter release probability, availability of readily releasable pool of synaptic vesicles (Dobrunz and Stevens, 1997), postsynaptic receptor desensitization (Koike-Tani et al., 2008) or surface mobility of postsynaptic receptors (Heine et al., 2008) have all been proposed to play an important role in frequency-dependent modulation of synaptic transmission.



(Erin M. Schuman, 2008)

Dopamine is a neuromodulator, that plays crucial roles in motor control, learning and memory, or addictive behavior formation (Hikosaka, 2007; Wise, 2004). Most dopaminergic neurons are located in two nuclei, the ventral tegmental area and substantia nigra compacta (Bjorklund and Dunnett, 2007). Activation of these neurons during animal learning has been well characterized in monkey. Schultz and colleagues examined the *in vivo* activities of dopaminergic neurons during a conditioning task. In this study, the activity of dopaminergic neurons appears to reflect differences between internal expectations and actual outcomes, i.e. expectation errors (Schultz, 1998). Thus, one function of the dopamine system is to provide information about the salience of environmental stimuli for learning (McClure et al., 2003).

THE PRODUCT: BMI CONTROLLER

With the above scientific data/information in perspective, the design of the BMI Controller is such that human safety is paramount while fulfilling its objective.

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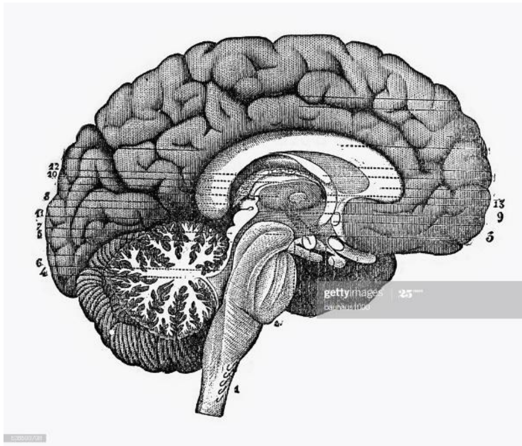

The Controller is designed as such that there will be an implantation of a micro-processing device/receptor in the midsection of the brain (just at the surface (can be on either hemisphere)) to enhance its capability to receive signal output from the brain.

This chip will have receptors made of polyvinyltoluene/polystyrene plastic with a length between 0.2mm to 1cm (size depends on brain density of the subject). The reason for choice of those plastics is that they are flexible which is a positive because they create leverage to facilitate easy brain movements without negative side effects (eg. Seizures). Also, evidential research has proven that photons are very high in these plastics and when placed with fiber, the photons increase by over 15%.

This is significant as it allows for scalability and improves bandwidth through the increase of wavelengths on the fiber.

Subsequent laser cooling on the dipole-allowed $^1S_0$-to-$^1P_1$ transition at 461 nm and the dipole-forbidden $^1S_0$-to-$^3P_1$ transition at 689 nm allowed us to load a new ensemble of atoms into the optical lattice roughly every 2 s. The atoms were spread over roughly 1 mm along the cavity axis, corresponding to around 2000 occupied lattice sites. (Matthew A. Norcia et al, 2016)

At 698 (813) nm, the 4-cm-long cavity mode had a waist size of 74 (80) μm. At a typical lattice depth of 100 μK, the frequency of axial (radial) motion in the trap was 170 kHz (270 Hz), giving a Lamb-Dicke parameter $\eta = 0.16$ in the axial direction (***46***). For the $|e\rangle$ to $|g\rangle$ transition studied here, $C = 0.33$, and the single-photon Rabi frequency was $2g = 2 \times 2\pi \times 3.7$ Hz for a maximally coupled atom. (Matthew A. Norcia et al, 2016)

These plastic receptors will then be connected/attached to a fiber-based sheath with silicon coating. These become effective as it will facilitate greater throughput in conversion from binary to analog and vice versa because there will be greater capabilities to create/draw data buses in nanometric context on the circuit while matching wavelengths will exist on the analog side of the device.

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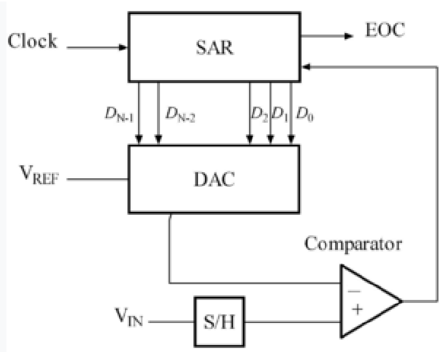
From what studies show, we will be able to acquire a bandwidth of 10nHz (Nano-Hertz) from these receptors, and also able to achieve more. This fully surpasses the 10 Micro-Hertz threshold for general neuro-communication.

Sample Analog to Digital Conversion:



Successive-approximation ADC block diagram

Key

DAC = digital-to-analog converter
EOC = end of conversion
SAR = successive approximation register
S/H = sample and hold circuit
V_{in} = input voltage
V_{ref} = reference voltage

For More information visit:
https://www.doulos.com/knowhow/vhdl_designers_guide/models/analogtodigital_converter_model/

The micro-processing device/receptor will connect wired or wireless to an external device attached to the subject’s ear or place of choice. There will be a hard (burnt-in) and soft address to facilitate security concerns. Therefore, the internal chip will only communicate with that specific external device unless they are officially programmed otherwise. With respect to data communication, 5G data communication will be required to guarantee proper sync between internal and external device. The BMI device will use the same to make communication with the Avionic Systems.

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THE BMIC ARCHITECTURE

The Brain-Machine-Interface Controller consists of the Micro-processing Implantation and an External Device, these have option of speaking wired/wirelessly with each other and the External Device to speak wired/wireless with an external control (computer terminal/interface or machine). The Micro-processing Implantation consists of Stimulation, Electrode Diagnostics, Power Management, Analog Amplifiers, Analog-to-Digital Converters, Processing Logic, Radio Frequency (RF) Transceiver and/Sensor Feedback. This connects to a Charging and Data Transfer Coil, which Connects to an External Device (effectively a wearable computer) that relates wired/wirelessly to a computer terminal.

The Cable Connectors will be placed just under the scalp. The External Device consists of an Operating System (preferably Linux), (1TB) Hard Drive (Solid State), Microprocessor (Intel 7th Generation Pentium Processor), Bio-Sensors, Input Device (Both Bio-Sensors and Input Device work to detect a computer terminal and position cursor on the screen through mental operations on the part of the user), (DDR 4) Random Access Memory (RAM), Battery Power (Lithium Ion, 4800mAh, 11.1 volts), Global Position System (that user could determine their location and also the Manufacturer or whoever the user gives express permission to) and Radio Frequency (RF) Transceiver (5G similar to the one above).

The Manufacturer would have the right based on user request to remotely troubleshoot any technical issues that may develop during use of the Device and the greater Controller (where necessary), or user could go in for in-person fixtures to the Controller and Device. However, the BMIC would be programmed as such to automatically raise a flag in the event of any technical issues that may develop during use of the Controller and Device.

The Microprocessing Implantation consists of twelve (12) Application-Specific-Integrated Circuits (ASICs) each containing 500 to 1000 electrodes. This results in 6, 000 to 12, 000 individually programmable amplifiers and 6,000 to 12,000 channels overall. This will enhance better reception of analog signals to the brain and transmission of signals thereto. The Language of choice is C++. Overall, there will be four (4) Microprocessing Implantations in the brain and as a result 24,000 to 48,000 electrodes from the Sensors to the External Device.

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STIMULATION:

Brain stimulation therapies can play a role in treating certain mental disorders. Brain stimulation therapies involve activating or inhibiting the brain directly with electricity. The electricity can be given directly by electrodes implanted in the brain, or noninvasively through electrodes placed on the scalp. The electricity can also be induced by using magnetic fields applied to the head. While these types of therapies are less frequently used than medication and psychotherapies, they hold promise for treating certain mental disorders that do not respond to other treatments. (National Institute of Mental Health, 2016)

From the Scientific Data/Information presented under "THE HUMAN BRAIN: NEURO-TRANSMITTANCE", the synaptic nerves respond to different frequency levels. Hence, the Stimulation Engine would be so designed that 6 ASICs (with their respective electrodes) would be placed among monosynaptic nerves and 6 ASICs (with their respective electrodes) would be placed among disynaptic nerves.

When the sensors detect a lapse in communication from the synaptic nerves the Microprocessor Implantation will detect such lapses and is automatically configured to generate the appropriate frequencies to stimulate such nerves. From research disynaptic nerves responds best to frequencies in the range of 50 to 200 Hertz, while monosynaptic nerves respond best to frequencies in the range of 10 microhertz and lower.

In disynaptic nerve communications lapse, the Stimulation Engine will generate 50 to 200 Hertz to stimulate activity. It will do this over a 30 second to 2 minutes period. It will automatically increase by the tens until positive responses are detected. While in monosynaptic nerve communications lapse, the Stimulation Engine will generate in the range from 10 microhertz to 10 nanohertz to stimulate activity. The Stimulation Engine in this situation will do continuous (non-time specific) frequency propagation until positive responses are detected.

The reason for the above approach, is that research has shown that monosynaptic nerves respond best to low continuous frequencies and disynaptic nerves respond best to short periods of high frequencies. Even though low frequency monosynaptic nerve(s) stimulation does trigger disynaptic nerve(s), the disynaptic nerves themselves respond to higher frequencies.

General Formula:

$S_{AM} = -0.5[\cos(2\pi(f_c + f_m)t) + \cos(2\pi(f_c - f_m)t)]$,

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$S_{FM} = \sin(2\pi f_c t + M \sin(2\pi f_m t))$

Where AM is Amplitude Modulation, FM is Frequency Modulation, f_c is Carrier Frequency, f_m is Message Frequency, t is period (in time) and M is Modulated Signal.

AMPLIFIERS AND ANALOG-TO-DIGITAL CONVERTERS:

An electronic amplifier (or amplifier, or amp) is an electronic system that increases the voltage and/or intensity of an electrical signal. The energy required for amplification is derived from the system's power supply. A perfect amplifier does not distort the input signal: its output is an exact replica of the input but of increased amplitude. It is therefore an active quadripole based on one or more active components (transistor, operational amplifier, etc.). (Henri Lilen, 2003)

Electronic amplifiers are used in almost all electronic circuits: they can elevate an electrical signal, such as the output of a sensor, to a voltage level that can be exploited by the rest of the system. They also increase the maximum available power that a system can provide to power a charge such as a radio antenna or an electroacoustic speaker. (Henri Lilen, 2003)

Pixel aspect ratio (often abbreviated PAR) is a mathematical ratio that describes how the width of a pixel in a digital image compares to the height of that pixel. (ITU, 2007)

The ratio of the width to the height of an image is known as the aspect ratio, or more precisely the display aspect ratio (DAR) – the aspect ratio of the image *as displayed;* for TV, DAR was traditionally 4:3 (a.k.a. fullscreen), with 16:9 (a.k.a. widescreen) now the standard for HDTV. In digital images, there is a distinction with the storage aspect ratio (SAR), which is the ratio of pixel dimensions. If an image is displayed with square pixels, then these ratios agree; if not, then non-square, "rectangular" pixels are used, and these ratios disagree. (ITU, 2007)

The aspect ratio of the pixels themselves is known as the *pixel aspect ratio* (PAR) – for square pixels this is 1:1 – and these are related by the identity:

SAR × PAR = DAR.

Rearranging (solving for PAR) yields:

PAR = DAR/SAR.

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For example, a 640 × 480 VGA image has a SAR of 640/480 = 4:3, and if displayed on a 4:3 display (DAR = 4:3) has square pixels, hence a PAR of 1:1. By contrast, a 720 × 576 D-1 PAL image has a SAR of 720/576 = 5:4, but is displayed on a 4:3 display (DAR = 4:3). (ITU, 2007)

In analog images such as film there is no notion of pixel, nor notion of SAR or PAR, but in the *digitization* of analog images the resulting digital image has pixels, hence SAR (and accordingly PAR, if displayed at the same aspect ratio as the original). (ITU, 2007)

The Application of Laplace And Fourier Transform

Laplace Transform (Berkeley Science, 2013)

The crucial property of the Laplace transform (it's also true for the Fourier transform) is that it transforms differentiation into multiplication by s, that is, for s = (σ ,ω)
L(*f '*)(s) = sL(*f*)(s) - *f*(0)

Recall the product rule for differentiation (uv)' = u'v + v'u,
integrating both sides gives

$$u(b)v(b) - u(a)v(a) = \int_a^b (uv)' = \int_a^b u'v + \int_a^b uv'$$

So, with u=$e^{-\sigma t}$(cos(ωt), -sin(ωt)), and dv = *f '*, we have u'=(-σ,-ω)u, and v=*f*, and

$$0f(\infty) - 1f(0) = (-\sigma,-\omega)\int_0^\infty f(t)e^{-\sigma t}(\cos(\omega t),-\sin(\omega t)) + \int_0^\infty f'(t)e^{-\sigma t}(\cos(\omega t),-\sin(\omega t))$$

so that
L(*f '*)(s) = sL(*f*)(s) - *f*(0)
The key factors were the product rule for differentiation, and the property that differentiating damped oscillation results in multiplying the damped oscillation by a constant.

Examples

The Laplace transform maps the complex plane (σ ,ω) to the complex plane (a, b). A point in the domain represents the damping factor of the exponential used to modify the function, and the and frequency of the Fourier transform, a point in the range represents the Fourier transform cosine and sine components at the frequency. Thus, 'complex numbers' are being used to represent different things for the domain and range of the Laplace transform.

We can take the Laplace transform of a damped complex cosine-sine, which is easy (see the derivative of damped oscillation above):

L[$e^{-\alpha t}$(cos(βt), sin(βt))](s) = $\int_0^\infty e^{-\alpha t}(\cos(\beta t),\sin(\beta t))e^{-\sigma t}(\cos(-\omega t),\sin(-\omega t))$

$$= \int_0^\infty e^{-(\alpha+\sigma)t}(\cos((\beta-\omega)t), \sin((\beta-\omega)t)) = \frac{e^{-\infty}(-,-) - e^0(1,0)}{(-\alpha-\sigma, \beta-\omega)} = \frac{-1}{(-\alpha-\sigma, \beta-\omega)}$$

and this result can be used to calculate the Laplace transform of real valued damped sine and cosine waves. These are key functions in Laplace transform analysis. With this result we can identify the function generating any transform that is the ratio of two polynomials (a rational polynomial).

Fourier Transform (Berkeley Science, 2013)

Periodic functions can be approximated by Fourier series. This result can be extended to represent any function as an integral of sine and cosine components. Let *f* be a function and define f_T to be the periodic extension of *f* on the interval -T/2 to T/2, that is, $f_T = f$ on the interval -T/2 to T/2 and f_T is periodic with period T. Then f_T can be approximated by a Fourier series. The Fourier series approximation uses the frequencies that are multiples of the base frequency 1/T cycles per second. As T increases, f_T approaches *f*, and the spacing between the frequencies in the series approximations, that is 1/T, decreases. In the limit, we will need to replace the summation of the series by an integral. The integral equals *f*, this is the Fourier Integral Theorem. The coefficients of the sine and cosine components are given by the Fourier transform.

The Fourier transform consists of the Fourier cosine transform and the Fourier sine transform. The Fourier cosine transform of *f* is defined for any real frequency λ cycles/second by

$$A_f(\lambda) = 2\int_{-\infty}^{\infty} f(t)\cos(2\pi\lambda t)$$

and the Fourier sine transform of *f* is defined by

$$B_f(\lambda) = 2\int_{-\infty}^{\infty} f(t)\sin(2\pi\lambda t)$$

The Fourier Integral Theorem (FIT) states

$$f(x) = \int_0^\infty A_f(\lambda)\cos(2\pi\lambda x)\,d\lambda + \int_0^\infty B_f(\lambda)\sin(2\pi\lambda x)\,d\lambda$$

We simplify by assuming that $f(x) = 0$ for $x < -T_0/2$ and $x > T_0/2$. We'll also assume *f* is even so that the sine transform is 0. The Fourier series coefficients for f_T (were f_T matches *f* for $-T/2 < t < T/2$, and is extended to be periodic with period T) are then

$$A_j = A(j/T) = 2/T\int_{-T/2}^{T/2} f(t)\cos(2\pi jt/T) = 2/T\int_{-\infty}^{\infty} f(t)\cos(2\pi jt/T) = A_f(j/T)/T \text{ for } j = 0,1,2...$$

We can approximate the FIT integral by dividing the range of frequencies into intervals of size h=1/T and summing with

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$$\int_0^{\infty} A_f(\lambda)\cos(2\pi\lambda x)d\lambda$$ <-

$$(1/T)\sum_{j=0}^{n} TA(j/T)\cos(2\pi jx/T) = \sum_{j=0}^{n} A(j/T)\cos(2\pi jx/T)$$ $= S_n(f_T, x)$

Explanation

In simple terms, Laplace and Fourier Transform are used in conjunction with each other to mitigate against the Nyquist Effect and bring sinusoidal (and other types of) waves to its pure form. Signals are amplified using Laplace Transform and hence exceeding the threshold to overcome noise/attenuation on a channel(s). Fourier Transform is then used to sub-divide sinusoidal waves (and also other types of waves) into periods of time. Here signals are looked at introspectively to remove any other electromagnetic interference and extract data for digitization and hence conveying an accurate representation of analog data in binary form.

The processing of the analog waves occurs 100 picohertz. The Microprocessor Implantation accepts 80, 000 samples per second (80 milliseconds or 80 Megabits per second) and process them using 16 Core Computers. This Operation overall happens so fast that the brain will not recognize.

The Nyquist Theorem, also known as the sampling theorem, is a principle that engineers follow in the digitization of analog signals. For analog-to-digital conversion (ADC) to result in a faithful reproduction of the signal, slices, called *samples*, of the analog waveform must be taken frequently. The number of samples per second is called the sampling rate or sampling frequency. (Margaret Rouse, 2005)

Any analog signal consists of components at various frequencies. The simplest case is the sine wave, in which all the signal energy is concentrated at one frequency. In practice, analog signals usually have complex waveforms, with components at many frequencies. The highest frequency component in an analog signal determines the bandwidth of that signal. The higher the frequency, the greater the bandwidth, if all other factors are held constant. (Margaret Rouse, 2005)

Suppose the highest frequency component, in hertz, for a given analog signal is f_{max}. According to the Nyquist Theorem, the sampling rate must be at least $2f_{max}$, or twice the highest analog frequency component. The sampling in an analog-to-digital converter is actuated by a pulse generator (clock). If the sampling rate is less than $2f_{max}$, some of the highest frequency components in the analog input signal will not be correctly represented in the digitized output. When such a digital signal is converted back to analog form by a digital-to-analog converter, false frequency components appear that were not in the original analog signal. This undesirable condition is a form of distortion called aliasing. (Margaret Rouse, 2005)

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The Nyquist–Shannon sampling theorem is a theorem in the field of digital signal processing which serves as a fundamental bridge between continuous-time signals and discrete-time signals. It establishes a sufficient condition for a sample rate that permits a discrete sequence of *samples* to capture all the information from a continuous-time signal of finite bandwidth. (Nemirovsky et al., 2015)

Strictly speaking, the theorem only applies to a class of mathematical functions having a Fourier transform that is zero outside of a finite region of frequencies. Intuitively we expect that when one reduces a continuous function to a discrete sequence and interpolates back to a continuous function, the fidelity of the result depends on the density (or sample rate) of the original samples. (Nemirovsky et al., 2015)

The sampling theorem introduces the concept of a sample rate that is sufficient for perfect fidelity for the class of functions that are band-limited to a given bandwidth, such that no actual information is lost in the sampling process. It expresses the sufficient sample rate in terms of the bandwidth for the class of functions. The theorem also leads to a formula for perfectly reconstructing the original continuous-time function from the samples. (Shannon, Claude E., 1949)

Perfect reconstruction may still be possible when the sample-rate criterion is not satisfied, provided other constraints on the signal are known (see § Sampling of non-baseband signals below and compressed sensing). In some cases (when the sample-rate criterion is not satisfied), utilizing additional constraints allows for approximate reconstructions. The fidelity of these reconstructions can be verified and quantified utilizing Bochner's theorem. (Shannon, Claude E., 1949)

RADIO FREQUENCY (RF) TRANSCEIVER:

With carrier aggregation (CA) and advanced-MIMO techniques, the New Radio (NR) devices can attain up to several Gb/s peak data-rate. The demand of high bandwidth has created a need for exploring high-frequency spectrum over 3GHz, while sustaining legacy Long Term Evolution (LTE) bands for LTE-NR dual connectivity (EN-DC). Since User Equipment (UE) requires small form-factor and low power consumption, a single-chip RF transceiver is essential to cover both NR and legacy protocols, simultaneously. This integrated CMOS (complementary metal-oxide-semiconductor) Radio Frequency Integrated Card (RFIC) that supports multimode and multiband applications including all the legacy 2G, 3G, 4G and stand-alone/non-stand-alone sub-6GHz 5G NR features.

According to the Third Generation Party Project (3GPP) (release 15) standards, 5G NR (New Radio) can operate in two frequency bands: FR1 and FR2 [1]. In this paper, a transceiver (TRx) operating in Time Division Duplex (TDD) mode at 3.5 GHz (FR1 band) is chosen for analysis. A

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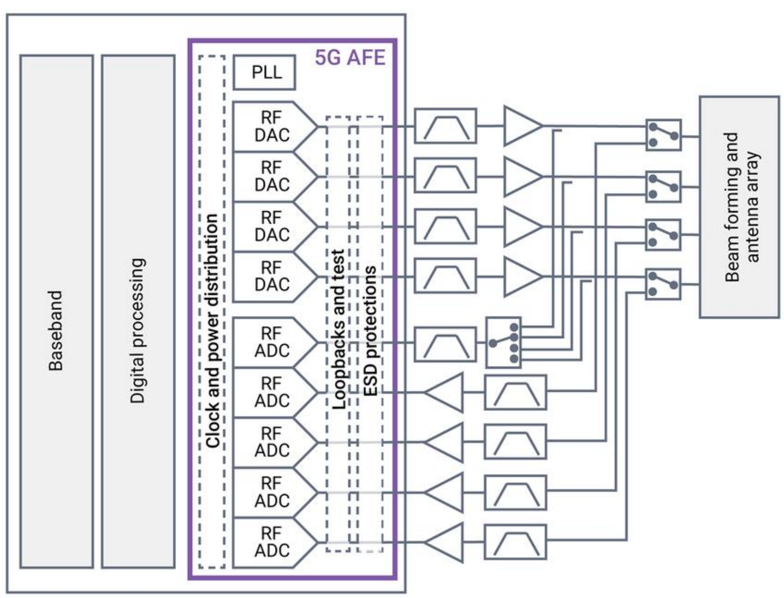
band pass filter is one of the crucial components in wireless transceiver (TRx) systems. The overall system specification and Radio standards requirement are mostly covered by Filter's specification. In TRx system, filters play a major role in improving the selectivity of the receiver, rejecting spurious harmonic noise generated within the system and making the system more immune to unwanted radio signals. (L. Punitha et al., 2019)

A typical configuration of a TDD based TRx system is shown in Figure 1. The Tx chain consists of a cascade of driver amplifier that conditions the input signal, a Band Pass Filter (BPF) operating at the desired frequency band, and a power amplifier (PA) to boost the signal to a required level for the antenna to transmit. Similarly, the Rx chain consists of a low-noise amplifier (LNA) to increase the signal power to an appropriate level for detection, a BPF, a digital attenuator for adjusting the gain of the system, and an amplifier (AMP) for signal conditioning. The antenna is connected to the Tx and the Rx chain through a single pole double throw (SPDT) RF switch. In addition, a directional coupler (DC) can be placed after the antenna for monitoring and calibration purposes. (L. Punitha et al., 2019)

5G RADIO FREQUENCY (RF) TRANSCEIVER CONFIGURATION



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ELECTRODE DIAGNOSTIC:

The medical electrode transfers the energy of ionic currents in the body into electrical currents that can be amplified, studied, and used to help make diagnoses.

Medical electrodes permit surface quantification of internal ionic currents, yielding an ordinarily non-invasive test for a variety of nervous, muscular, ocular, cardiac, and other disorders that might otherwise have required surgical means to verify their presence. For instance, muscular exams using electrodes may produce evidence of diminished muscle strength and can discriminate between primary muscle disorders and neurologically-based disorders, in addition to detecting if a muscle is truly weak or seems so due to other reasons. The electrodes are typically easy to use, fairly cheap, disposable (or easily sterilizable), and often unique in the tasks they help to perform. The essential role of the electrode is to provide ideal electrical contact between the patient and the apparatus used to measure or record activity. (Medical Encyclopedia, 2020)

PROCESSING LOGIC:

This coordinates all the activities of the Microprocessor Implant Device. According to Unitronics, is a ruggedized computer used for industrial automation. These controllers can automate a specific process, machine function, or even an entire production line.

The Processing Logic receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters. Depending on the inputs and outputs, a Processing Logic can monitor and record run-time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Processing Logics are a flexible and robust control solution and are adaptable to any application.

POWER MANAGEMENT:

The Power Management System is designed according to Advanced Configuration and Power Interface (ACPI). ACPI is open standard that Operating Systems use to discover and configure hardware components to perform power management operations such as putting unused components to sleep and perform status monitoring.

The Power Management System is used to: reduce overall energy consumption, prolong battery life for portable and embedded systems, reduce cooling requirements, reduce noise and reduce operating costs for energy and cooling.

Lower power use means lower heat dissipation (leading systems stability) and less energy use and that reduce costs and reduce negative impacts on people and the environment.

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SENSOR FEEDBACK:

Sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. A sensor is always used with other electronics. (S. Bennett, 1993)

The Sensor(s) relating to the Microprocessor Implantations are used for interfacing with the Electrodes causing the External Device to speak with the Microprocessor Implantations and vice versa. This is different from the Bio-Sensors in the External Device which are used to interface with the computer terminal.

SPECIFICATIONS OF MICROPROCESSOR IMPLANTS

Channels	24, 000 to 48, 000
Root Mean Square Noise	7.2 microvolts
Amplifier/Analog-Digital-Converter Power	3.3 microwatts
Spike Detection	2,000 nanoseconds
Stimulation Resolution	0.2 microamperes and 3.0455 microseconds
Die Size	4 x 5 mm

COMPUTER TERMINAL

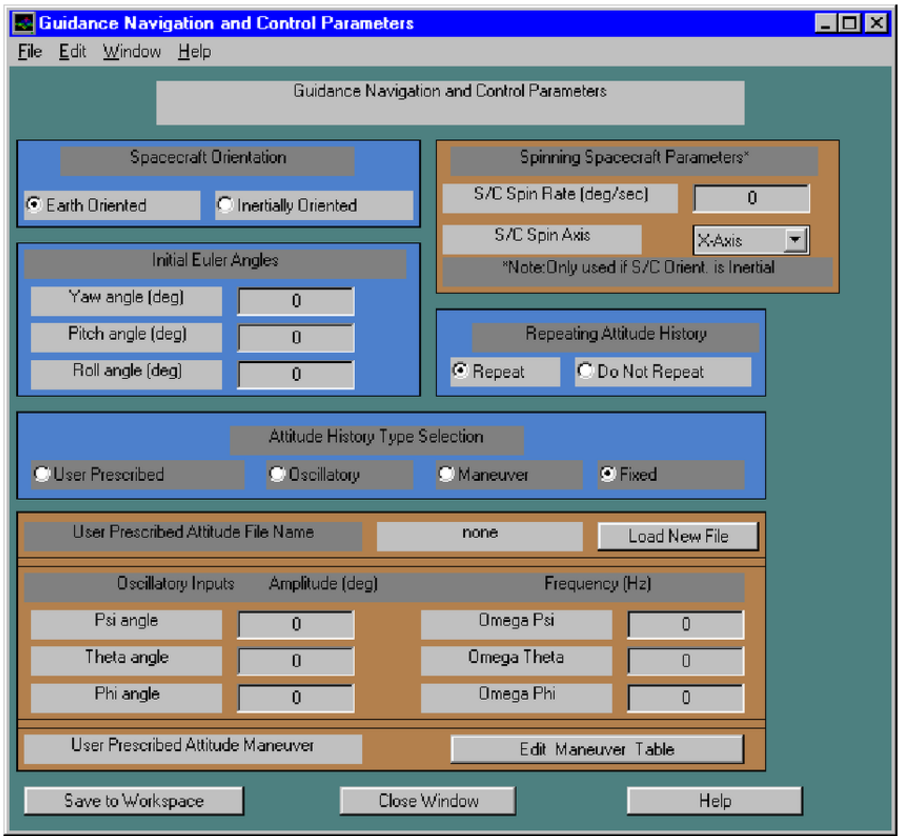
This specialized terminal will facilitate all the needs of the user. This terminal will relate with the servers responsible for the Guidance, Navigation and Control (GN and C) Sub-System, the Electrical Power Sub-System (responsible for providing and storing electrical energy, user can use it to adjust lighting in the space vehicle) and the Thermal Control Sub-System (responsible for regulating temperature throughout the space vehicle).

The user can connect with the computer terminal via an USB cable or wirelessly. The terminal will consist of soft controls placed on the screen. All controls for the space vehicle will be on the screen of this terminal. The user will have the luxury of utilizing soft buttons, textboxes, etc. to enter and commit commands. The screen will have options to which server the user wants to switch to or login to (may incorporate a special window that pops up with the information and GUI for that server).

There will be an option for the user to change controls, for example from input via textboxes to a soft toggle or lever control on the screen, that is, when maneuvering the vehicle. The user will be able to log into the Electrical Power Sub-system to adjust lighting and any authorized electrical needs. The user will be able to log into the Thermal Control Sub-system to adjust the

temperature throughout the vehicle. The terminal will have camera footages displaying every aspect of the space vehicle.

Guidance, Navigation and Control (GN and C) Sub-system



When the user attempts to change the speed and orientation of the space vehicle, a window displaying the effect of the proposed move will appear. The user will see how the vehicle would appear once the command has been committed and a possible warning the user should brace for. Then the user has the option to commit the command or to make changes. For continuous motion controls, for example, a steering, in place of such, the user can enter (double) floating point numbers, (if not using soft controls (eg. Toggle Control)) to input data.

The user will have control over the engines of the vehicle collectively or individually. This becomes important in cases where spacecraft needs to perform Soyuz Rendezvous and docking to facilitate proper docking and to avoid collisions and possible errors when attempting to dock. This is also important when disengaging from dock to allow for smooth transition and movement away from the International Space Station (ISS) or any docking facility.

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The GN and C also known as AOCS (Attitude Orbit Control System) is responsible for the orientation, position, velocity and angular velocity (navigation) of the space vehicle. It is responsible for force and torque (control) along a trajectory as defined in the Guidance Function. It measures the current state of the space vehicle and inspects the data from the sensors and it interfaces with the actuator hardware and applies the required forces and torques.

Sensor measurements are usually corrupted with sensor noise, drift and biases, the Navigation Function has a filter to correct the attenuation present in the measurements. In the absence of sensors to measure all the dynamical states, the navigation tool reconstructs some states to measure the hardware. This is done through Sensor Fusion and Robotic Applications and Stochastic Filtering Techniques (such as variations of Kalman Filters – regular, extended and unscented).

The Kalman filter uses a system's dynamic model (e.g., physical laws of motion), known control inputs to that system, and multiple sequential measurements (such as from sensors) to form an estimate of the system's varying quantities (its state) that is better than the estimate obtained by using only one measurement alone. As such, it is a common sensor fusion and data fusion algorithm. (Kalman, R.E., 1960)

In the extended Kalman filter (EKF), the state transition and observation models need not be linear functions of the state but may instead be nonlinear functions. These functions are of differentiable type. (Kalman, R.E., 1960)

$$\begin{aligned}\mathbf{x}_k &= f(\mathbf{x}_{k-1}, \mathbf{u}_k) + \mathbf{w}_k \\ \mathbf{z}_k &= h(\mathbf{x}_k) + \mathbf{v}_k\end{aligned}$$

The function f can be used to compute the predicted state from the previous estimate and similarly the function h can be used to compute the predicted measurement from the predicted state. However, f and h cannot be applied to the covariance directly. Instead a matrix of partial derivatives (the Jacobian) is computed. (Kalman, R.E., 1960)

At each timestep the Jacobian is evaluated with current predicted states. These matrices can be used in the Kalman filter equations. This process essentially linearizes the nonlinear function around the current estimate. (Kalman, R.E., 1960)

When the state transition and observation models—that is, the predict and update functions f and h —are highly nonlinear, the extended Kalman filter can give particularly poor performance. This is because the covariance is propagated through linearization of the underlying nonlinear model. The unscented Kalman filter (UKF) uses a deterministic sampling technique known as the unscented transformation (UT) to pick a minimal set of sample points (called sigma points) around the mean. The sigma points are then propagated through the nonlinear functions, from which a new mean and covariance estimate are then formed. (Wangyan Li et al., 2019)

The resulting filter depends on how the transformed statistics of the UT are calculated and which set of sigma points are used. It should be remarked that it is always possible to construct new

UKFs in a consistent way. For certain systems, the resulting UKF more accurately estimates the true mean and covariance. (Wangyan Li et al., 2019)

This can be verified with Monte Carlo sampling or Taylor series expansion of the posterior statistics. In addition, this technique removes the requirement to explicitly calculate Jacobians, which for complex functions can be a difficult task in itself (i.e., requiring complicated derivatives if done analytically or being computationally costly if done numerically), if not impossible (if those functions are not differentiable). (Wangyan Li et al., 2019)

The Guidance Function specifies the desired dynamical states either in a waypoint as a function of time or Trajectory Generator that will smooth out the transition between the waypoints. It also calculates the error between the desired states and estimated states to compute the trajectory tracking error between these states and feed the signal to the onboard Controller. This is to ensure the required torque be applied to the different actuators onboard the space vehicle and that the vehicle follows the desired trajectory.

The GN and C Sub-system also facilitates reconfiguration while the spacecraft is in orbit.

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